非洲 Beni n 國農村婦女的體重、體重指數和身體組成的季節性變化

Seasonal changes in body weight, body mass index (BMI) and body composition of rural Beninese women

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Seasonal changes in body weight and body mass index (BMI) of two groups of rural Beninese women were investigated throughout a one-year cycle. Average body weight showed seasonal fluctuations of 1.4 kg in South Beninese women and of 3.8 kg in North Beninese women. Weight changes were reflected in changes of BMI distribution. In a sub-group of South Beninese women (n=24) body composition was estimated in a pre- and post-harvest season using D_2O dilution, bio-electrical impedance (BIA), skinfold measurements, and BMI equations. Seasonal weight change in the sub-group was 0.8±1.6 kg (P<0.05). Each method indicated that there was a significant change in fat-free mass (FFM) but not in fat mass from the pre-harvest to the post-harvest season. Fat mass assessed by D_2O was 12.3±3.3 kg which was significantly lower (P<0.01) than the assessment by the other three methods. The difference between D_2O and skinfold method was 1.5±2.1 kg, between D_2O and BIA 1.8±2.1 kg, and between D_2O and BMI 2.0±2.0 kg. It is concluded that various methods to estimate body composition are not interchangeable in field conditions.

Introduction

Energy intake and energy expenditure of rural populations in developing countries are often subject to seasonal fluctuations resulting in changes in body weight. Loss of body weight usually occurs during the pre-harvest season, when food availability is limited and physical activity, as dictated by the agricultural calender, is high. These pre-harvest weight losses range from 0.5 – 4.0 kg[1]. After the harvest, when food is available in abundance, body weight increases again. The seasonal weight changes correspond on average to 2–7% of the body weight and it may be questioned whether these changes affect health and physical capacity. With regard to this aspect measurements of body composition in different seasons could provide additional information.

Most information about seasonal changes in body composition of people from rural areas in Africa was obtained by measuring skinfold thickness[2–6]. Although this method is very suitable for use under field conditions, its application in African and Asian populations is questionable because the equations to predict fat mass from skinfold thickness were developed in white populations[7–9]. A factor of concern are possible differences in fat patterning between populations[10–12]. Therefore, it is useful to compare different methods to assess body composition.

In the present study seasonal changes in weight and BMI throughout a one-year cycle of two groups of rural Beninese women are presented. The two groups came from distinct climatological zones which enables investigation of possible difference in seasonal weight changes. Corresponding changes between a pre- and a post-harvest season in fat mass and FFM were estimated in a sub-group by using a skinfold thickness method[7], bioelectrical impedance measurements[13], D_2O dilution and mass spectrometry[14], and by using a BMI equation[15].

Subjects and methods

Study area

The study of body weight was carried out in two distinct districts of the Republic of Benin: Dogbo and Manta. Dogbo is situated in the south west of Benin, about 70 km from the coast. Manta is situated in the north west of Benin, about 500 km from the coast. The population in both study sites consists largely of small scale farmers. Annual rainfall in Dogbo is about 1100 mm and is mainly distributed over two rainy seasons. Bimodal distribution of yearly rainfall permits two harvests a year of the main food crop maize in July and December. Manta has only one rainy season, but annual rainfall is about the same as in Dogbo. The main crops sorghum, millet and fonio are harvested once a year in October and November.

Body weight study

In Dogbo the measurements of body weight were carried out from October 1987 to October 1988, covering two pre-harvest periods. In Manta the measurements of body weight were carried out from February 1988 to March 1989, covering one pre-harvest period.

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In Dogbo 150 women were selected and in Manta 50 women, using the following criteria. The subjects had to be between 20 and 45 years. The women had to be non-pregnant, and had to have between two and five children (the youngest child being at least 9 months old). All subjects had to have farming as their main occupation.

Every two weeks body weight was measured between 7.00 and 8.00 am at a central place in each village using SECA platform spring balances (SECA, Hamburg, Germany). The balances were attached to wooden boards and were place on a horizontal surface. Before each weighing session the balances were checked, and calibrated if necessary, using calibration weights of 40.0 and 60.0 kg. The subjects were wearing a minimum of clothing and body weight was measured to the nearest 100 g (no correction was made for the clothing which weighed at most about 300 g). Height was measured once at baseline with the subjects standing on a horizontal surface against a vertically placed wooden board with the heels together, chin chucked in and stretched upwards to full extent and the head in a Franfurt plane. The heels, buttocks and shoulders were in contact with the wooden board to which a flexible metal tape had been fixed.

When women became pregnant during the observation period, data collection was continued but the results of these women were not used in the present analysis. When a subject was not present at four non-successive weighing sessions (or more), or at two successive weighing sessions during one year, his/her data were excluded from the analysis. A data set covering the whole period of measurement was obtained for 82 women from Dogbo, and for 34 women from Manta. Some characteristics of the subjects are presented in Table 1.

Table 1. Selected characteristics of subjects.

	Body weight study		Body composition study
	Dogbo	Manta	Dogbo
n	82	34	24
Age (years)	32.8±5.8*	31.0±8.0	34.4±5.6
Weight (kg)	52.0±9.3	51.3±7.3	52.1±5.8
Height (cm)	158.0±6.0	158.0±5.0	159.9±5.5
BMI (kg/m^2)†	20.8±3.4	20.6±2.7	20.3±1.6
Sum wrist diameter (cm)	10.0±0.8	NM	9.8±0.9
Sum knee diameter (cm)	16.3±1.0	NM	16.8±1.1
Shoulder width (cm)	34.0±1.9	NM	34.2±1.7

*Mean±SD; values at the start of the study. †BMI: body mass index (weight/height^2).

Body composition study

Out of the group of 82 women in Dogbo, a sub-group of 24 women was selected in the year after the body weight study (on basis of willingness to participate). Characteristics are given in Table 1. Each woman was measured once during the pre-harvest season (May–June) and once during the post-harvest season (September–October).

Anthropometrical measurements

Body weight was measured using the same equipment and procedures as during the weight study. Body weight was registered to the nearest 100 g, and the measured values were corrected for the minimum of clothing the subjects were wearing (estimated weight of clothing 300 g). Biceps, triceps, subscapular and supriliac skinfold thicknesses were measured in triplicate to the nearest mm using a Holtain skinfold calliper (Holtain Ltd, Briberian, UK) (pressure 10 g/mm^2). Measurements were made on the left side of the body by the same person. Percentage fat was estimated using the equations of Durnin and Womersley[7] and fat mass calculated from these results and body weight.

Bioelectrical impedance

Bioelectrical impedance (BIA) was measured with the subject in a supine position with limbs away from the trunk as described by Lukaski[13] with a body composition analyser (RJL Systems, Inc, BIA-101, Detroit, MI, USA). Measurements were made at about 9.00 am and the subjects were asked not to eat beforehand (no instructions were given regarding the drinking of water). FFM was calculated using the following equation of Lukaski[16]. $FFM = 0.734\ Ht^2/R + 0.096Xc + 0.116Wt + 0.878G - 4.033$, in which Ht=height (cm), R=Resistance, Xc=reactance, Wt=weight (kg), G=sex (1 for male, 0 for female). Fat mass was calculated as the difference between body weight and FFM.

Deuterium oxide

Total body water (TBW) was measured using a deuterium oxide dilution technique[14,17]. Women of one village were gathered in the morning at about 10 am in one place where they stayed throughout the time of the experiment under supervision of a research assistant. They were asked not to eat anything before the measurement. We took a pre-dose sample of body water (1–2 ml of saliva) and then administered a carefully weighed dose of 15–20 g of a 20% D_2O solution (0.4 g of the solution per kg FFM as estimated by skinfold measurements; about 0.1 g D_2O/kg body weight). After a 2 hour equilibration period the first post-dose saliva samples were taken, and after 3 hours a second post-dose saliva sample was taken. During the equilibration period the subjects neither ate nor drank. The increase in deuterium oxide level after dosing was calculated using the average of the 2 hour and 2 hour post dose saliva samples. Saliva samples were kept frozen at –20°C for storage. Analysis was carried out at Glasgow University, Scotland, UK, by isotope ratio mass spectrometry (VG-Isogas, Middlewich, Cheshire, UK). Analytical precision, estimated as the mean difference between duplicate analysis of TBW was 0.9%. The deuterium dilution space was divided by 1.04 to correct for overestimation of TBW[18]. FFM was defined as TBW/0.73 and the fat mass as the difference between body weight and FFM.

BMI equation

A subjects' body composition was assessed from BMI using the equation of Deurenberg et al.[15]:

$$\%\text{body fat} = 1.20\ BMI - 10.8\ G + 0.23\ age - 5.4,$$

in which BMI is (kg/m^2), G is gender (1 for men, 0 for women), and age (in years) should be higher than 16 years.

Statistical analysis

Changes in body weight in the sub-group from pre-harvest to post-harvest season were tested by a paired t-test. Changes in fat mass and FFM between seasons and differences in assessment between methods were tested using analysis of variance for repeated measurements of SPSS/PC+ (results explained by method and season)[19]. Correlation between two methods was tested using Pearson's correlation coefficient.

Results

The results of the longitudinal body weight measurements are shown in Figure 1. For Dogbo women, weight increased after the harvest period in November and remained relatively stable until March. From March onwards (pre-harvest) weight gradually decreased until the middle of June (0.9±2.1 kg, P=0.001). From the middle of June weight rapidly increased to reach the highest level in August (post-harvest). The difference in body weight between June and August was 1.4±1.7 kg (P=0.001). In Manta, body weight decreased from March until the end of April (1.1±1.5 kg, P=0.001), but then increased again, and in the second half of May weight was similar to the value of February. Subsequently during the pre-harvest season from the end of May until September body weight decreased with 2.6±2.1 kg (P=0.001). From September to February (harvest and post-harvest) a large increase in body weight occurred (3.8±1.7 kg, P=0.001). Figure 2 shows the difference in BMI distribution between the pre-harvest and post-harvest season. BMI during the pre-harvest season in Dogbo was 20.5±3.2, while it was 20.9±3.4 during the post-harvest season in September (P<0.01). BMI values in Manta during pre- and post-harvest seasons were respectively 19.5±2.6 and 20.8±2.5 (P<0.01).

The increase in body weight between the pre-harvest season and the post-harvest season for the sub-group of women of the body composition study was 0.8±1.6 kg (P=0.02) (Tables 1 and 2). BMI also increased significantly with 0.3±0.6 kg/m^2 (P=0.02). The increase in the sum of skinfolds of 1.6±7.4 mm was not statistically significant. The ratio triceps/subscapular and subscapular/supra iliac were, respectively, 1.07 and 1.01 in the pre-harvest and 1.06 and 0.98 in the post-harvest season. Assessed values of body composition are presented in Table 3. Analysis of variance for the

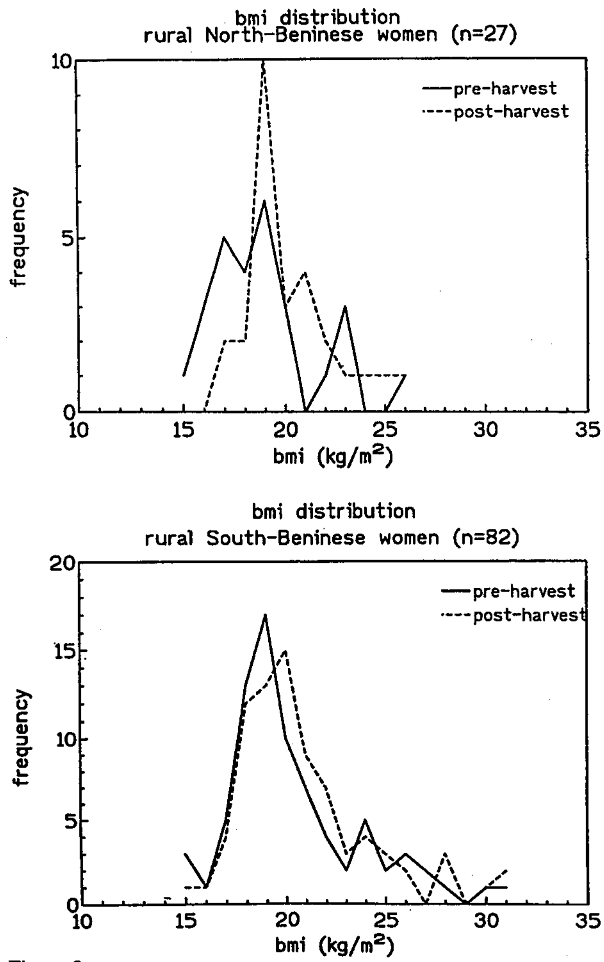

Figure 2.

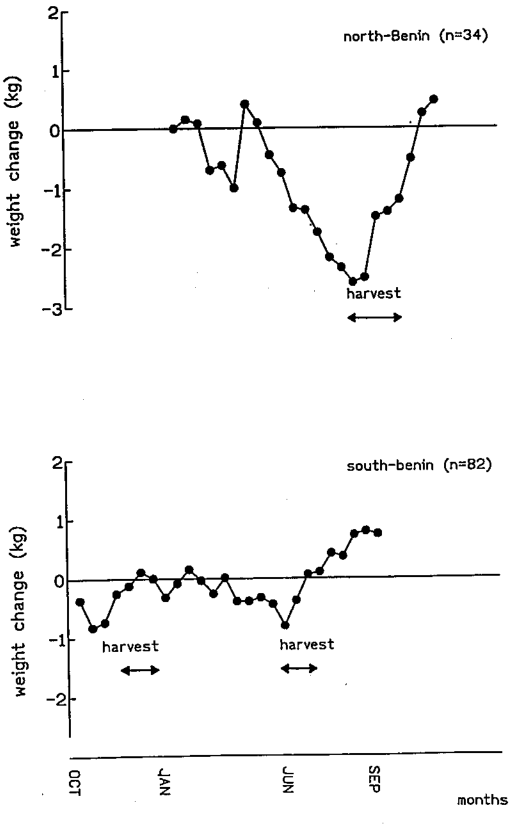

Figure 1. Seasonal weight changes of rural women in North and South Benin, West Africa.

FFM explained by the four different methods and the two seasons indicated that the FFM increased significantly between the pre- and post-harvest season (P<0.01). This increase in FFM was 1.1±2.6, 0.5±1.0, 0.8±1.6 and 0.4±0.8 kg as assessed by D_2O, skinfold, BIA and BMI, respectively. The fat mass did not show statistically significant seasonal changes. Since no interaction existed between method and the season in the analysis of the results, fat mass estimations obtained in both seasons were pooled in order to study the degree of agreement between the four methods. The combined fat mass value (n=48) were 12.3±3.3, 13.8±3.3, 14.1±2.9, 14.3±2.7 kg, for, respectively, the D_2O skinfold thickness, BIA and BMI methods. The results obtained by the four methods showed significant correlation (P<0.001) (Table 4). Figure 3 shows the relationship between fat mass estimated by D_2O and each of the methods. However, although a significant correlation existed between all four methods the average estimated fat mass differed. Fat mass assessed by the D_2O dilution method was significantly lower than the values obtained by the other techniques (P<0.001). The differences in fat mass were 1.5±2.2 kg (P<0.001) for skinfold thickness vs D_2O method, 1.8±2.1 kg for BIA vs D_2O method, and 2.0±2.0 kg for BMI vs D_2O method. There existed no significant difference between the values obtained by skinfold thickness, BIA or BMI equation method.

Discussion

Seasonality is a distinct feature of life for most African rural populations having a significant effect on energy metabolism

Table 2. Anthropometric measurement results.

	Pre-harvest	Post-harvest
n	24	24
Weight (kg)	52.1±5.8*	52.9±5.7†
BMI (kg/m^2)	20.5±1.7	20.8±1.7†
Biceps (mm)	5.2±1.7	5.5±1.6
Triceps (mm)	13.2±2.8	13.4±2.8
Subscapular (mm)	12.3±4.0	12.7±4.8
Suprailiac (mm)	12.2±5.2	12.9±6.4
Sum of skinfolds (mm)	42.9±11.5	44.5±13.4
% Fat‡	25.9±4.0	26.1±4.6

*Results presented as Mean ± SD. †Different from value in pre-harvest season (P=0.02). ‡Fat percentage as obtained by sum of four skinfolds.

Table 3. Fat mass and fat-free mass (FFM)† assessed by four methods in two seasons.

	Pre-harvest (n=24)	Post-harvest (n=24)
D_2O:		
Fat mass (kg)	12.4±3.4*	12.1±3.3
FFM (kg)	39.7±3.6	40.8±4.1
Skinfold:		
Fat mass (kg)	13.6±3.2	14.0±3.5
FFM (kg)	38.5±3.6	38.9±3.6
BIA:		
Fat mass (kg)	14.1±3.0	14.1±2.9
FFM (kg)	38.0±3.5	38.8±3.8
BMI:		
Fat mass (kg)	14.1±2.7	14.5±2.8
FFM (kg)	38.0±3.3	38.4±3.2

*Results presented as Mean ± SD.
†FFM increased significantly between the pre- and post- harvest season; analysis of variance (P<0.01).

Table 4. Correlation coefficient matrix of fat mass assessments by four methods (all methods are significantly correlated; P<0.001).

	D_2O	Skinfolds	BIA	BMI
D_2O	1.0000	0.7904	0.7781	0.7859
Skinfolds	0.7904	1.0000	0.7714	0.8324
BIA	0.7781	0.7714	1.0000	0.8576
BMI	0.7859	0.8324	0.8576	1.0000

and therefore on body weight and body composition[1]. In South Benin as well as in North Benin, body weight decreased significantly during the pre-harvest season. The decrease of body weight of Dogbo women during the pre-harvest season represents about 2.0–2.5% of the body weight during the post-harvest season. This decrease is comparable with decreases in body weight reported for other rural African populations who live in areas with two rainy seasons[20–22]. In Manta with only one rainy season per year, the loss of body weight during the pre-harvest season was larger, representing about 6% of the post-harvest body weight. Similar values have been reported for a nomadic population in Niger[23]. Body weight losses were reflected in changes in BMI, which decreased significantly during the pre-harvest season on both populations. James et al.[24] proposed to classify chronic energy deficiency in adults according to BMI. They argued that a BMI<17 is incompatible with good health and physical capacity. During the post-harvest season all women in Manta had a BMI<17, while during the pre-harvest season 15% of the women had a BMI<17. In Dogbo, 8% of the women had a BMI<17 during the pre-harvest season, while this was 5% during the post-harvest season.

Considering the above, it is of interest to determine the composition of the body tissue lost and gained during the different seasons. All four methods indicated that the increase in

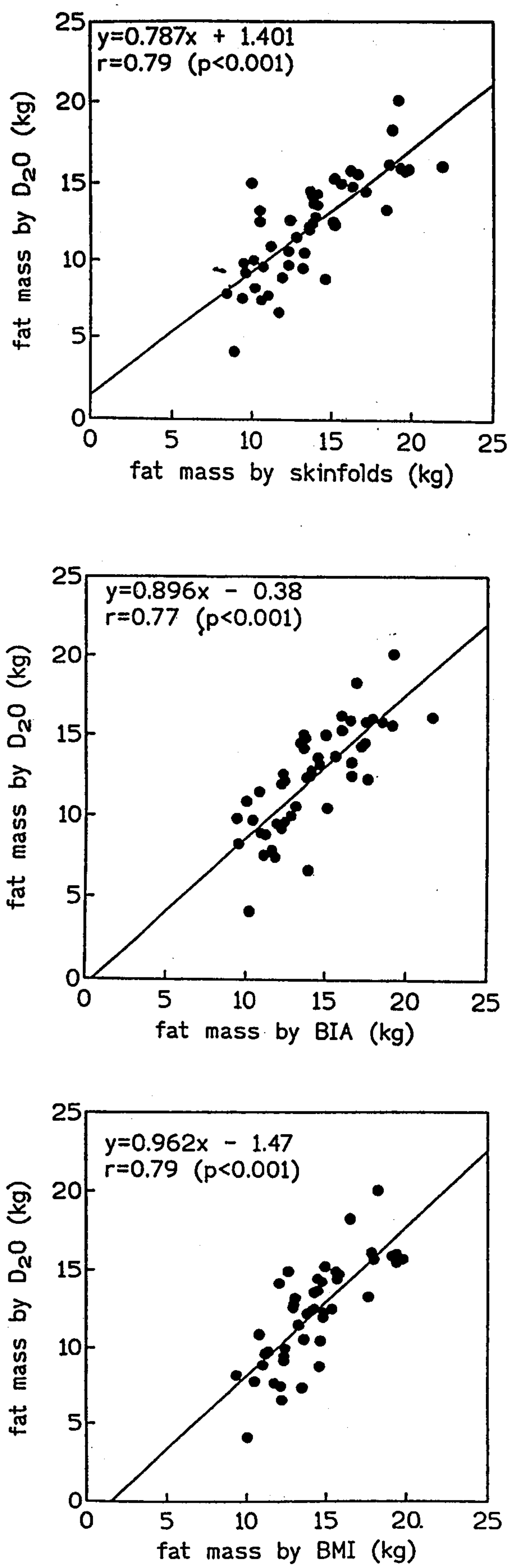

Figure 3.

body weight during the post-harvest season in the sub-group of women seemed to consist mainly out of FFM. This suggests, furthermore, that the loss of body tissue during the pre-harvests season did not mainly consist of energy-dense fat mass but also of FFM. Therefore, the weight loss during the pre-harvest season may negatively influence physical capacity.

Although the fat mass estimations by the different methods were highly correlated, the actual values within individuals as well as the average values showed differences. Of the four applied methods to assess fat mass the values obtained by the D_2O method gave the most outlying values. It is not the intention of this paper to discuss intensively possible causes of these differences which has been done elsewhere[25]. However, with respect to the D_2O and BIA method it is important to note that several studies reported that the density of FFM of blacks is greater than in whites[26,27]. A greater density of the FFM means that the water content may be lower than the generally applied value of 73%. Furthermore, changes in fluid balance throughout the day, which are likely to occur in tropical countries, may negatively affect the applicability and reliability of D_2O and BIA methods to assess FFM under field conditions in tropical countries[28].

With respect to estimates of fat mass from skinfold thickness measurements it is assumed that the selected sites for measurement of skinfolds represent the average thickness of the adipose tissue. In blacks the distribution of subcutaneous fat may be different as in whites as indicated by the ratio of skinfold thickness of triceps and subscapular[12]. It is of interest to note that the ratio of the skinfold thicknesses of triceps and subscapular of 1.07 in our Beninese women is similar to the same ratio reported for American black women of 1.04[12], while the ratio was 1.19 and 1.02 for, respectively, women from Senegal[29] and Upper-Volta[30]. Although a difference in fat patterning and in density of FFM exists between whites and blacks a good agreement has been reported between assessed fat mass by D_2O and skinfold measurements in blacks from the United States[12] and by densitometry and BIA in West Indian blacks[31]. However these measurements were carried out under laboratory conditions using equations specific for blacks[31].

It cannot be concluded which method of body composition assessment most accurately estimated fat mass in the Beninese women. Average BMI was 20.3 and body fat assessed by the D_2O method was 24% of the total body weight, while it was 26–27% for the other methods. BMI and fat percentage of Ethiopian were respectively 19.0 and 21.0%[21], while values of women from Burkina-Faso were, respectively, 20.5 and 19.3%[30]. Gambian women were reported to have a BMI of 20.5 and a relatively low fat percentage of 21.5%[17]. West Indian black women had a BMI of about 20 and a fat percentage of 25.0% as estimated by BIA[31]. These reported BMI values vary from 19.0–20.5, while the related fat percentages vary from 10–26% , and therefore do not give any indication which of the used methods is most accurate.

Significant seasonal changes in body weight occurred in the women in North and South Benin. These seasonal changes in body weight may affect physical capacity as indicated by the low BMI which a proportion of population had during the pre-harvest season. Furthermore, the body composition study in the sub-group of women revealed that seasonal weight changes do consist of significant changes in FFM. Dugdale and Payne[32] argued that the seasonal changes in body weight are the consequence of an adapted optimum strategy of farmer populations in which optimal available physical capacity is balanced against a need to minimize food losses due to food storage. The findings in the present study do not support this argument because an optimum strategy would require seasonal changes in fat mass only. The composition of the weight gain of the Beninese women is in line with an equation published by Forbes[33] which predicts the composition of weight gain depending on body fat content. Considering the difference in results of the assessed fat mass obtained by the four methods more research which compares available methods to assess body composition in African populations is warranted, especially under field conditions.

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